SUCCESSFUL ESTABLISHMENT OF *ENCARSIA ?HAITIENSIS* DOZIER (HYMENOPTERA: APHELINIDAE) IN TORRES STRAIT, QUEENSLAND, FOR THE BIOLOGICAL CONTROL OF *ALEURODICUS DISPERSUS* RUSSELL (HEMIPTERA: ALEYRODIDAE)

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Abstract

Introductions of *Encarsia ?haitiensis* Dozier into Australia for the biological control of *Aleurodicus dispersus* Russell were made directly into the field on Boigu Island, Torres Strait, Queensland. The methodology used to import the parasitoid and its subsequent release throughout the Torres Strait region is described. In all cases establishment of the parasitoid was recorded within 20 months of releases, commonly quite sooner. There appeared to be an inversely proportional relationship between the numbers of parasitoids released at a location and the time taken for the parasitoid to establish.

Introduction

Aleurodicus dispersus Russell, the spiralling whitefly, is a major pest of many fruit trees, vegetables and ornamental plants in the tropics (Waterhouse and Norris 1989). The species is believed to have originated in the wet tropics of Central and South America (Russell 1965, Caballero 1994). It has a high reproductive rate, an ability to rapidly disperse (Kumashiro *et al.* 1983, Waterhouse and Norris 1989) and an extensive host range (Wen *et al.* 1994, Lambkin 1999) and, consequently, is now almost pan tropical in distribution (CAB International 1993, Lambkin 1996, 1999), even extending into subtropical and temperate climates (Russell 1965, Wen *et al.* 1994, Manzano *et al.* 1995). The first sighting of *A. dispersus* on Australian territory was by the Northern Australian Quarantine Strategy [NAQS] in 1991 on Boigu Island in Torres Strait, Queensland (Fig. 1). It subsequently spread to almost all of the inhabited Torres Strait islands (Waterhouse and Sands 2001) and now occurs as far south as Mackay, Queensland.

An undescribed species of *Encarsia* Foerster, known as *E. ?haitiensis* (Kumashiro *et al.* 1983, Waterhouse and Norris 1989) has been used almost exclusively for the biological control of this pest. It reproduces parthenogenetically and consequently a high proportion of progeny are females (Lambkin 1996). Waterhouse and Sands (2001) concluded that it was undescribed and incorrectly named (Hawaii Department of Agriculture 1981, Kumashiro *et al.* 1983) because the female resembles the yellow-coloured female of true *E. haitiensis* Dozier, which is recorded from Cuba and Haiti (De Santis 1979), where it is known to parasitise species of *Aleuroglandulus* Bondar (Aleyrodidae). *E. ?haitiensis* is believed to have originated in Trinidad (Kumashiro *et al.* 1983) and was first introduced into the Hawaiian Islands in 1979 (Hawaii Department of Agriculture 1981, Kumashiro *et al.* 1983). Following its establishment there, it was introduced throughout the

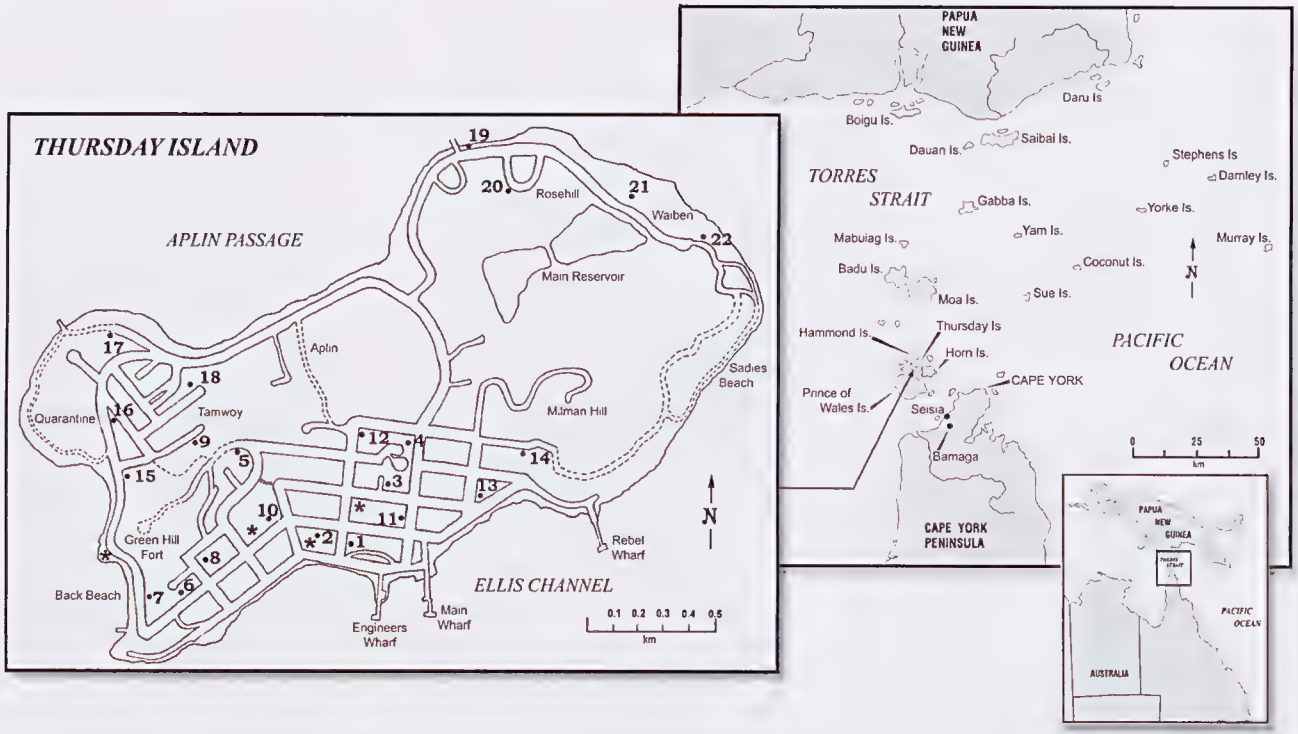

Fig. 1. Torres Strait region: relative position of Thursday Island arrowed; Thursday Island: numbered parasitoid release sites, positions indicated by an * are where parasitoids were discovered outside release sites within two months of releases.

Pacific where it has significantly reduced pest numbers (Waterhouse and Norris 1989, Waterhouse and Sands 2001). This same *Encarsia* species was released on Boigu Island in 1992 soon after *A. dispersus* was detected.

Despite its widespread use as a control agent for *A. dispersus*, there is nothing formally published that outlines the methods used to collect and import *E. ?haitiensis*, release it and confirm its establishment. In this paper I describe the methods used in the Torres Strait region to import, collect, release and confirm establishment of *E. ?haitiensis* in *A. dispersus* populations. Also documented is the parasitoid's establishment in the region and parameters that may control its rate of establishment are discussed.

Materials and methods

Importing and releasing parasitoids into Boigu Island

Following the incursion of *A. dispersus* into Boigu Island, the Australian Quarantine and Inspection Service (AQIS) and the Australian Nature Conservation Agency (ANCA) approved the importation and release of *E. ?haitiensis* to control the pest. At that time, the Secretariat of the Pacific Community (SPC) (then the South Pacific Commission) in Fiji was culturing the parasitoid and consignments from this colony, guaranteed by SPC to be pathogen and hyperparasitoid free, were being used to control pest infestations throughout the Pacific (Waterhouse and Norris 1989). Therefore, in 1992 two consignments of parasitoid pupae were imported from Fiji into Boigu for release directly into the field (Fig. 1, Table 1). The consignments contained adult parasitoids and parasitoid pupae inside whitefly nymphs free of plant material, in sealed plastic vials (70 mm high, 50 mm diameter) with moist paper wicks. The moist wicks provided water for the adult parasitoids and maintained high humidity inside the vials during transport. All adult parasitoids died in transit and the vials containing the parasitoid pupae inside whitefly nymphs were opened and suspended horizontally using narrow gauge wire, within infested vegetation as close as practicable (maximum distance 100 mm) to nymphal stages of *A. dispersus*. Because of windy or squally conditions at the time of both releases, vials containing the parasitoid pupae were confined with target infestations in fine gauze sleeves under plastic shelters. The sleeves and plastic shelters were removed after approximately 10 days when parasitoid emergence was estimated to be complete. Dead parasitoids (adult or pupae) remaining in all release vials were counted after the release periods to determine the proportion of successful emergence and, therefore, the number of parasitoids released.

Collection and release of parasitoids in other Torres Strait locations

After establishment of *E. ?haitiensis* on Boigu was confirmed, parasitoid pupae inside whitefly nymphs free of associated plant material were collected and transported from Boigu to Thursday Island for release (Fig. 1). Parasitoid pupae were collected by gently rubbing the white, flocculent wax off the

Figs 2-7. (2) *Aleurodicus dispersus*: late instar nymphs; (3) release vials for *Encarsia ?haitiensis* with parasitised late instar *A. dispersus* nymphs attached to fluted paper; (4-7) *A. dispersus*: (4) live late instar nymph showing normal yellow body colour; (5) late instar nymph showing dark body containing *E. ?haitiensis* parasitoid pupa; (6) previously parasitised late instar nymph showing adult *E. ?haitiensis* parasitoid emergence hole in exoskeleton of nymph; (7) late instar nymphs and adults. All scale bars = 1 mm.

dorsal surface of 3rd and 4th (late) instar *A. dispersus* nymphs and then microscopically assessing them for parasitism. Parasitised nymphs were then gently transferred from their leaf substrate using fine, sharp-nosed jeweller's forceps, to the edge of thick, fluted paper that was firmly inserted into plastic vials (Fig. 3). When assessing for parasitism 3rd and 4th instar nymphs were grouped together as both instars are difficult to distinguish because of their covering of white, flocculent wax (Fig. 2). A piece of moistened flat sponge was fitted into the bottom of each vial under the fluted paper to maintain high humidity and avoid desiccation of parasitoid pupae. The plastic vials were 55 x 45 mm with plastic screw cap lids and each lid had a single hole 15 mm in diameter covered with fine stainless steel screen of aperture 0.5 mm. Most often 50 parasitoid pupae were placed in each vial (arrowed in Fig. 3). As parasitoid pupae vibrate when just pupated, only vibrating pupae were collected so that no adult emergence occurred in transit. Emergence of adult parasitoids was further minimized or avoided by maintaining the shipment at a low temperature (≈20°C) and by restricting collection and transport times to two days in total.

The method of release on Thursday Island was similar to that used on Boigu except the gauze sleeves and plastic shelters were not used, the piece of moistened flat sponge fitted into the bottom of each vial was removed before hanging the vial in the field (Fig. 3) and, on Thursday Island, there were more releases made and more *E. ?haitiensis* released (Table 2). Subsequently, parasitoid pupae were then progressively collected from Thursday Island and released over *A. dispersus* at other locations in the Torres Strait region (Table 1). The method of collection and release was the same as used for Thursday Island releases.

Confirming establishment of parasitoids

To confirm establishment of *E. ?haitiensis* at locations where releases were made, 100 mature leaves were collected randomly from each infested plant, leaves examined microscopically, and late instar nymphs of *A. dispersus* were assessed for parasitism. Late instar nymphs were chosen as suitable stages to assess for parasitism as they were easily identified by the covering of large amounts of white, flocculent wax (Figs 2, 4) and because parasitoid pupae could be seen microscopically through the exoskeleton of the nymph (arrowed in Fig. 5). Mature larvae of *E. ?haitiensis* are yellow and can be seen inside *A. dispersus* nymphs. Parasitoid pupae are at first yellow but after approximately 24 hours (in tropical temperatures) they darken and begin to vibrate within the whitefly nymph. Pupae stop vibrating 1-2 days before eclosion and when emerging, the adults make a neat round emergence hole (arrowed in Fig. 6) in the abdominal end of the parasitised nymph. Unparasitised nymphs are creamy yellow in colour (arrowed in Fig. 4) and, after eclosion, have a ragged Y shaped emergence hole in the thoracic area of the empty nymphal shell.

The other stages of *A. dispersus* were considered too difficult to accurately count, as adults (Fig. 7) are highly mobile and egg and young nymphal stages are too difficult to identify when embedded and concealed in wax produced by older instars. Presence of the parasitoid (i.e. assumed establishment) at each site was identified by the presence of at least one parasitised or previously parasitised nymph in the 100 leaves examined. A quick indication of parasitisism can be made prior to microscopic examination by viewing infested leaves through strong background light, such as sunlight, then checking with the naked eye for the presence of parasitised nymphs that appear predominantly black when compared with the creamy yellow colour of live nymphs.

Table 1. Releases of *Encarsia ?haitiensis* over *Aleurodicus dispersus* in the Torres Strait region from 1992-1996.

Release location	Source of parasitoids	Number of individuals released	Number of release sites	Release dates	Earliest confirmed establishment
Boigu Is	Ex SPC culture	92	2	Apr, Sep 1992	Feb 1994
Thursday Is	Ex field Boigu	1271	22	May, Jun, Aug, Oct 1994	June 1994*
Horn Is	Ex field Boigu	220	3	May, Jun 1994	Aug 1994
Prince of Wales Is	Ex field Thursday	219	3	Aug 1994	Oct 1994
Hammond Is	Ex field Thursday	100	2	Nov 1994	Oct 1995
Murray Is	Ex field Thursday	54	2	Nov 1994, Mar 1995	Apr 1996
Yorke Is	Ex field Thursday	73	2	Nov 1994, Mar 1995	Aug 1999^
Saibai Is	Ex field Boigu	100	1	Mar 1994	Apr 1995
Dauan Is	Ex field Boigu	113	1	Mar 1994	April 1995
Yam Is	Ex field Boigu	100	2	Mar 1994	November 1995
Coconut Is	Ex field Thursday	100	2	Oct 1995	Oct 1995#
Damley Is	Ex field Thursday	308	2	Apr 1996	not revisited
Seisia (Cape York)	Ex field Thursday	776	11	Aug, Oct, Nov 1995, Jun 1996	Jun 1995#, Mar 1996

*Field sampling while releases were still occurring suggested that populations were established as early as June 1994; #*E. ?haitiensis* were found already established; ^Populations of *A. dispersus* and *E. ?haitiensis* were not observed between 1994 and 1999 [J.G. Grimshaw, NAQS record].

Parasitoid establishment results and discussion

Establishment of the parasitoid was recorded within 20 months of release, commonly quite sooner, at all sites in the Torres Strait region (Tables 1 and 2). On Coconut Island and at Seisia, parasitoids were discovered prior to any releases being made (Table 1). Interestingly, on Yorke Island (Table 1) low numbers of *A. dispersus* were first discovered in November 1994 and parasitoids were released at that time. However, *A. dispersus* and its parasitoid were not observed again on the island until August 1999 (Table 1), despite regular searching by NAQS officers (J.G. Grimshaw, pers. comm., 2002). Sampling on Boigu and Thursday Islands in March 2001 confirmed that the parasitoid was still established and widely distributed.

Table 2. Releases of *Encarsia ?haitiensis* over *Aleurodicus dispersus* infestations at 22 sites on Thursday Island. Site numbers refer to locations marked on Fig. 1.

Site number	Number released	Released	Host plant on which *A. disperses* colonies were located and released over	Date of confirmed establishment
1	100	June 1994	*Terminalia catappa*	March 1995
2	100	June 1994	*Malvastrum coromandelianum*	August 1994
3	50	June 1994	*Psidium guajava*	March 1995
4	21	June 1994	*Acalypha wilkesiana*	April 1995
5	100	June 1994	*Acalypha wilkesiana*	March 1995
6	100	May 1994	*Acalypha wilkesiana*	June 1994
7	50	August 1994	*Quisqualis indica*	April 1995
8	50	August 1994	*Musa* sp.	April 1995
9	50	August 1994	*Manihot esculenta*	August 1995
10	50	August 1994	*Carica papaya*	March 1995
11	50	August 1994	*Acalypha wilkesiana*	March 1995
12	50	August 1994	*Psidium guajava*	April 1995
13	50	August 1994	*Acalypha wilkesiana*	April 1995
14	50	August 1994	*Acalypha wilkesiana*	April 1995
15	50	October 1994	*Acalypha wilkesiana*	April 1995
16	50	October 1994	*Carica papaya*	April 1995
17	50	October 1994	*Musa* sp.	April 1995
18	50	October 1994	*Terminalia catappa*	April 1995
19	50	October 1994	*Terminalia catappa*	April 1995
20	50	October 1994	*Musa* sp.	April 1995
21	50	October 1994	*Terminalia muelleri*	April 1995
22	50	October 1994	*Acalypha wilkesiana*	April 1995

In general, across the Torres Strait region, numbers of parasitoids released at every location were roughly inversely proportional to parasitoid establishment times (Tables 1 and 2). For example, on Boigu Island, where a small number of parasitoids were released on two occasions, establishment of the parasitoid

seemed slow and localised as, in February 1994, parasitism was still unrecorded on some hosts in the village, even at and close to where the two releases were made. In contrast, on Thursday Island, where a much larger number of parasitoids were released at 22 sites, establishment of the parasitoid occurred more rapidly with its detection recorded at all release sites within 12 months (Fig. 1, Table 2). Moreover, significant movement of the parasitoid was confirmed on Thursday Island by its detection well outside the release areas in the southwest of the island in August 1994, less than two months after the first introduction (Table 2). Discovery of the parasitoid in *A. dispersus* populations on Coconut Island and at Seisia without deliberate releases being made indicates that random unintentional introductions of parasitoids do occur. Parasitoids may be introduced on infested plant material, as movements of such material have been observed in the Torres Strait region (unpublished observations). The disappearance of *A. dispersus* and the parasitoid for approximately five years on Yorke Island in late 1994 may have resulted from a local extinction of the pest and the parasitoid on the island, with a reintroduction of both occurring some time just prior to 1999.

In conclusion, the results from introductions of *Encarsia ?haitiensis* in the Torres Strait region to control *A. dispersus* indicate that establishment can occur from a small number of introductions using relatively few parasitoids, but faster establishment can be achieved by making more releases each with a larger number of parasitoids.

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